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Research Article

Changing Face Of The Apparel Industry By Incorporating Industry 4.0 And Paving Way For Industry 5.0

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Abstract

The COVID-19 pandemic has hampered the economy of the entire world. One of the deeply affected units was the apparel industry, which was worth almost 1.4 trillion U.S dollars. With social distancing, panic and fear in the minds of everyone, it became apparent that digitization brought about by Industry 4.0, is the new normal. The evolution of all the five Industrial Revolutions is discussed in this paper. It also highlights how the apparel industry has incorporated emergent technologies of Industry 4.0 like Artificial Intelligence, Blockchain, 3D-Printing, Cloud computing and Data Analytics in its manufacturing and marketing units. The impact of the pandemic has made the stakeholders of all businesses to halt, ponder and progress towards a new horizon for sustainability. The challenges of Industry 4.0, how and why the transition of the apparel industry from Industry 4.0 to Industry 5.0 took place is highlighted in this paper. This article represents a theoretical aspect and proposes a novel foundation for incorporating Industry 6.0 in the wake of the pandemic.

Keywords: Artificial Intelligence, Blockchain, 3D-Printing, Cloud computing, Data Analytics, IoT, Industry 4.0, Industry 5.0, Industry 6.0

Introduction

The Five Industrial Revolutions have shaped the economies of the world. History has shown that the building block for each revolution was laid by the previous revolution. [1] Many projects and programs are being executed around the globe that utilizes the marvels of the industrial revolution. In this paper we will concentrate on the features, advantages, disadvantages and challenges of Industry 4.0. It is interesting to note that the garment industry revolutionized by integrating the features of Industry 4.0. The most important aspect of Industry 4.0 is digitization. The apparel business was a flourishing unit due to ecommerce and the fashion pundits predicted a two-digit growth in its revenue in 2020. The apparel industry had already utilized the aces of Industry 4.0 and was making profits, but it all went in vain. COVID-19 engulfed the entire world by the end of 2019 and deeply impacted the economy, industries and humans worldwide.

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The apparel industry too came under its hammer and suffered great losses as customer's interests now shifted to staples and medical supplies. Clothing took a backseat as fashion and luxury items lost their hold on consumers due to change in lifestyle. Needs of customers shifted to comfort wear and sustainability rather than fast fashion. People became more health conscious and shifted their interests to exercise wear and sportswear. Work from home culture also added to this transition in customer interests. Lockdown disrupted the entire supply chain and led to closing down of SMEs. The link between suppliers and manufacturers was disrupted incurring huge losses to both the parties. Sitting at home resulted in a lot of thinking and discussions and surveys were conducted to boost up sales and revamp the industry. Many changes were suggested and usage of emerging technologies like Artificial Intelligence, IoT, Data Analytics, Machine Learning were promoted. The proposal for smooth progression from Industry 4.0 to Industry 5.0 in the apparel business was also suggested. As in Industry 4.0 full automation was the mantra whereas in Industry 5.0 human touch was added to automation of units. In the proceeding topics it will unfold how the garments industry is coping up with the COVID-19 pandemic by grasping the boons of Industry 4.0 and Industry 5.0. The focus will be on the applications, challenges and comparative analysis of Industry 4.0 and Industry 5.0 and its influence on the clothing industry and the directives for Industry6.0.

Motivation of the Study

Industrialization is a boon to mankind and is continuously upgrading itself. The motivation of the study is to analyze its impact on environment, humans and the world's most flourishing and alluring industry- the apparel industry.
1. First and foremost objective was to study in detail the design principles, features, advantages and challenges of Industry 4.0 and understand how the apparel business has adopted the principles of Industry 4.0.
2. Second important objective was to identify the role of Industry 5.0 on the apparel industry for its growth and its influence in mitigating the impact of coronavirus pandemic on the apparel market.
3. The design principles, features, advantages and challenges imposed by Industry 5.0 and its comparison with that of Industry 4.0 is also another motivating factor for this study.
4. To propose and study the futuristic Industry 6.0 and its features.

Industrial Revolutions

Before we delve into the implications it is interesting to follow the Journey and History of the five Industrial Revolutions and their influence on the world's economic development. The main features of all the five Industrial Revolutions as shown in Figure 1 are discussed below.
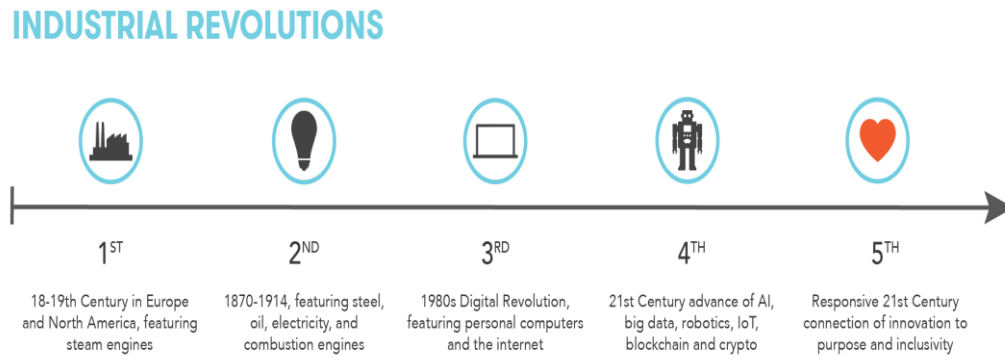
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Figure 1: Industrial Revolutions [8]

The First Industrial Revolution (1760)

It marked the era of mechanization and shifting of agriculture dominated economy to urbanization by providing work to people in industries. Steam power and waterpower were used in industries and invention of steam engine led to development of railroads.

A transition took place in both transportation and the textile industry due to industrialization. [2][3]

The Second Industrial Revolution (1870)

It was the era in which electricity, oil and gas emerged as the new sources of energy. Invention of internal combustion engine and automobiles and development of steel, chemical industries and means of communication like telegraph and telephone marked their existence in this period. It improved the socio-economic condition of the world and provided more employment opportunities. The textile industry grew by manufacturing artificial and chemical based fabrics with enhanced durability in the form of texture and color. [2][3]

The Third Industrial Revolution (1969)

This period saw the rise of electronics, biotechnology, telecommunications and computers. The third revolution opened its doors to research, space expeditions, inventions of PLCs-Programmable Logic Controllers and Robots, giving rise to high level of automation in offices and production lines. [3] The development of the Internet was also quite exemplary during this period. The garment industry also took advantage of this revolution. [2]

The Fourth Industrial Revolution or Industry 4.0 (2011)

The term Industry 4.0 was first introduced by the executive chairman of the World Economic Forum, Klaus Schwab in 2011 in an article published by Foreign Affairs. [4] The fourth industrial revolution happened in the start of the third millennium with the INTERNET as a major role changer. Many emerging technologies like robotics, artificial intelligence, the Internet of Things, quantum computing, nanotechnology, biotechnology, the Industrial Internet of Things, 3D printing, 5G wireless technologies were a part of it. [3] Industry 4.0 enhanced the connectivity and communication of the entire world.

Despite the marvels of Industry 4.0, it led to the acknowledgement that the advancement in technology and ecommerce loosened the desire of service to humankind. This situation was so aggravated that some of the torchbearers of the fourth Industrial Revolution withdrew some of their intellectual property rights and brought them out in the open, as they did not want to be held responsible for the aftermaths. Many Captains of the Industry 4.0 presumed that some of the

novel technological developments could be Orwellian or destructive for the people. The automation of industries led to reduction in jobs for humans. [6]

So now the question arises as to what can be expected from the fifth industrial revolution and will it help to improve humanity? An analysis of the features of Industry 5.0 leading to further development of industries and people is provided below.

The Fifth Industrial Revolution or Industry 5.0

It did not take even a decade for Industry 5.0 or 5IR to surface. [5] If Industry 4.0 emphasized on the transformation of factories into IoT-enabled smart facilities interconnected via cloud servers, Industry 5.0 is set to focus on the collaboration of humans and machines. The succession of each Industrial Revolution in the modern world has witnessed higher risks of de-humanizing the economic progress, which might be disastrous for the existence and viability of both humans and the environment. [6] The fifth industrial revolution is trying to bring the attention back to humanity. All the experts have opinionated and concluded that 5th Industrial revolution is an improved extension of the 4th Industrial revolution. [5] Thus it can be assumed that the 5IR is derived from 4th revolution, further refining its features. [6] According to an article developed in collaboration with the World Economic Forum, which stated that, the Fifth Revolution focused on adopting the best practices of technology and innovation rendering better service to humanity. [6][8]

Keeping this as a foundation, it can be foresighted that the 5th industrial revolution, uses a combination of AI (Artificial Intelligence) and quantum computing that will bring back the connectivity of humans and machines together at the workplace. [7][8] The manufacturers and marketers can exploit the unique traits of AI, that helps in enhanced decision making for all units of production and retail. [6]

Apparel Industry

With the overview of the five industrial revolutions the point of discussion is about the Apparel Industry and its integration with Industry 4.0 and the affect of pandemic on it. Followed by this is the in depth study of Industry 4.0, its design principles, features and challenges. Then there's a review about Industry 5.0 and what it has to offer to the apparel business for facilitating its growth and sustainability.

Global Market Strength Of Apparels

The global market value of the apparel industry is mentioned below.
- The retail apparel market of the world is worth $1.4 trillion. [9]
- The footwear market of the world is worth $366 billion. [9]
- India is the fifth largest market for fashion consumers. [9]
- The fashion business in the United Kingdom is valued at 69 billion dollars. [9]

The apparel/fashion Industry was one of the worst hit industries during the pandemic. It's supposed to be at its all time low. It's becoming increasingly difficult and challenging for the global fashion market to hold its position as a topmost industrial unit. Moreover due to digitization and fast fashion, the dynamics of the apparel industry is dramatically changing. To succeed amid the shifting tides, companies need to enhance their competence, agility, adaptions, intelligence and flexibility in their production and supply channels. Digitization started with Industry 4.0 with the rise of the INTERNET. The discussion as to how Industry 4.0 revolutionized the apparel industry is stated below.

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The Apparel Industry and Its Survival during COVID-19 with the help of Industry4.0

The pandemic has made everyone realize the need of digitization more than ever. Digitization was also the main takeaway of Industry 4.0. The fourth industrial revolution, brought about the much-needed transformation in the world of technology, mass customization and advanced manufacturing. In the Industry 4.0 the initial strategy was to transform manufacturing agents from fully physical systems to cyber-physical systems (CPS). [4] Thus, Industry 4.0 is based on the CPS communicating with each other through the Internet of Things (IoT). [3] Real-time information exchange between Cyber-Physical Systems required an efficient and secure method of storage because of availability of abundant data. Cloud storage emerged as the best option for it. A huge amount of data mining and data filtering techniques were applied to generate useful information from these vast unprocessed data lakes. This mined and refined data was combined with IoT, giving birth to a new concept called the Industrial Internet that bridged the gap between the physical and digital worlds. [4]

The global apparel business is one of the most agile industries. The fast-moving nature of fashion compels the apparel industry to be always one step ahead of the market trends. This posed a huge challenge to the apparel business.

The dynamics of the apparel industry is changing at a fast pace. [12] To quench the thirst of voracious apparel consumers, garments should be unique and novel to make it a personalized statement of self. Moreover with the transition from offline to online many smaller players have entered the garments business and are establishing their mark in the global market. [12][15] Germany's online retail brand, Zalando, has expanded its brand to almost fifteen countries in a span of six years. Under Armour, a sportswear and footwear company of USA has tripled its revenue in the past five years because of online sales.

Before the pandemic the garments industry was expected to double its revenue by 2020. Much of this growth was expected to be from the developing markets, and the Asian consumers, who were migrating into the middle class and had started to view clothes as one of the most important symbol of their new lifestyle. These consumers spent more on tourism and shopping. By 2020, overseas spending of Asian-Pacific customers were supposed to triple, almost $600 billion. The Chinese consumers partook in 75 percent of sales in the luxury goods market. But all this could not be achieved as expected because of the Covid-19 pandemic.

Industry 4.0

A detailed explanation of the design principles, advantages, disadvantages, major challenges and its integration with the apparel industry are mentioned herewith.

Design Principles Of Industry 4.0 [13] and its Integration with the Apparel Industry

The garment industry was approaching its doom but online markets and digitization soon aided to uplift it but at a slower pace. Let us see the pre-pandemic integration of apparel industry with the design principles of Industry 4.0 as shown in Figure 2 below.
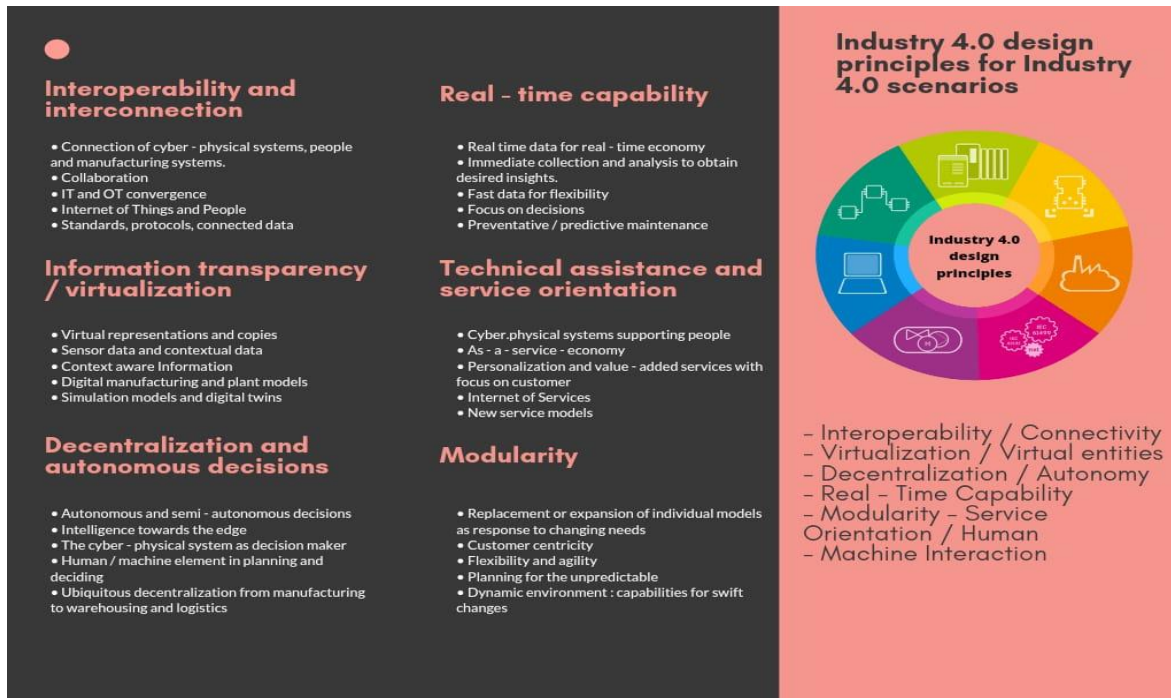
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Figure 2: The design principles of Industry 4.0 [13]

1. Interoperability and Interconnection. [13]

It is the integration of industrial machines, tools and processes through IoT and supporting machine-to-machine communication. This gave rise to the concept of Industrial IoT (iIoT), [14] which is a subset of IoT that focuses on enhancing the productivity and reliability in data analysis and data collection for industries like health care, energy, transportation, tourism, manufacturing, and many more. [38] The apparel industry also inculcates this feature explained in the following examples.

a) Garment IO developed by a startup in Egypt [39] is a software solution with durable smart terminals on ground to track production and a seamless interface on screen to boost your business. It combines cloud-based software with Machine Learning (ML). A factory in Egypt is using this software that integrates ML and data analytics to help floor managers in accurate decision-making. Every worker of the factory is given an electronic card and a smart terminal, which works in the same way as a credit card machine. Whenever a batch of work is completed, like sewing an order of shirts, the workers can scan their card on the terminal and the tag attached to the bundle of shirts. The smart terminal records the amount of order the worker has done, the time frame in which the order was completed and the pending job. The manager on his cloud can access this information, in real-time and can directly reward the workers for reaching their daily production targets and also provide them with immediate feedback. [15]

b) MES (Manufacturing Execution System) is a smart information system tool that enables managers to connect, control and monitor the factory floor. A drone is installed in the manufacturing wing of the production houses. The drone hovers above each production unit and with IoT integration, keeps a check on the functioning and quality of the production and does production scheduling, production management and quality monitoring for each and every machine. [11]

c) Fujitsu produced a new IoT measuring device that will dramatically improve and revolutionize the technique of measuring and of sizing of apparels. [10]

d) Windgo, [16][17] a company of USA, has researched, developed, and produced variety of sensor-based smart and intelligent digital products. A few patented product examples are smart bandages, diapers, and socks. These items are embedded with IoT based smart sensors that take biological readings of the wearer's body and give real-time information to the mobile device connected with it. One of the patents, the Windgo Baby 1, 2, 3 informs the parents and caretakers about the contents of the diaper so that action could be taken accordingly. Features can also be set for diaper rash minimization, absorption modes, and scent compensation modes.

2. Information transparency/virtualization. [13]

All industries should follow ethical codes of conduct. The companies should be transparent in their dealings and should adhere to fair trade policies and practices. Due to exposure and awareness, customers are craving for increased transparency in the entire supply chain, starting from gathering of the raw material to the delivery of the end product.

    a. LVMH is a Luxury brand, which uses Blockchain technology to trace the supply chain. These technologies bring awareness and enhance the confidence and trust of the customers on authenticity of the product. [15]

    b. Gap and Zara are providing a new experience to their customers through virtualization. COVID-19 has reduced physical contacts so virtual mirrors serve as the new fitting room where consumers can virtually try on the dresses and chose and buy the one they like.

3. Technical Assistance And Service Orientation [13]

AI based computerized machines can enhance and support workers efficiency and effectiveness. 3D printing, use of drones to monitor the various functions in production lines, smart tags and kiosks as well as contactless delivery and purchase are some of the features which the apparel industry is utilizing. Data analytics is used to predict future trends and demands.

4. Decentralization And Autonomous Decisions [13]

It is the implementation of technical systems that can act and execute tasks on their own. Use of robots, IOT and drones can help speeding up the tasks and monitoring of the production floors of the factories. It has paved way for evolution of smart factories. [30]

5. Real-Time Capability [13]

Data analytics, Augmented and Virtual Reality can give real-time predictions and true to life experiences to manufacturers and consumers. Virtual Mirrors or Virtual fitting rooms can give real-time visual experience of how a clothing will look on the customer without physically trying it. [14]

6. Modularity [13]

Different features of Industry 4.0 handle each segment of the industry. Each segment can be monitored for its functions separately and then connected by a common platform to enhance profitability. Data analytics can be used for filtering information and forecasting trends. AI and ML can help the consumers to choose their entire wardrobe by intelligent mix and match suggestions. Each module has something to offer. 3D printing can speed up production by computerized designing and cutting. Kiosks and chatbots can help to

search stores without physical intervention. [14][15] Thus it can promote social distancing, as it is needed for safety due to the pandemic.

Advantages of the Industry 4.0

Industry 4.0 manifested the eon of smart machines, storage systems and production facilities that can autonomously exchange information, trigger actions and control each other without human intervention. The advantages of Industry 4.0 are

1. Industry 4.0 was responsible for
   - Reducing the cost of Production by 10–30%;
   - Decrease in cost of Logistics by 10–30%;
   - Decrease in Quality management costs by 10–20%. [4]

2. Industry 4.0 promoted the following:
   - Availability of The Internet and IoT.
   - Integration of Manufacturing and Business Units with Intelligent Systems.
   - Efficient production lines and smart products.
   - Application of AI, Data Analytics, Cloud technology, Robotics, Blockchain technology, 3D printing, crypto currencies, and more to enhance productivity and retail. [4]
   2. A new concept in the form of smart factory evolved that includes CPS, IoT, cloud storage and cyber security in the manufacturing workspaces to provide autonomy and efficient functioning.

Drawbacks of Industry 4.0

Every revolution has two sides. Flip side of benefits of Industry 4.0 are mentioned below.
1. Automation of the entire production unit resulted in reduction of jobs for humans. Machines had overpowered humans by taking their jobs. [4]
2. Fear in the minds of humans regarding doubts of their capability to work in tandem with machines gave rise to stress and other health problems. [4]
3. Automation was more expensive and skilled labor was unavailable to operate or monitor the functioning of these machines. [4]
4. Machines posed a greater threat to the environment when disposed off or required dumping. The non-degradable materials used presented a threat to both Flora and Fauna. [4]
5. There was an increase in unemployment rate in the world because of increase in automation. [4]

Major Challenges of Industry 4.0

Some of the challenges of Industry 4.0 were:
1. To keep up with the changing face of industry due to complete automation by maintaining ecological and economical balance. [4]
2. To enhance productivity and profits without dehumanizing the manufacturing industry through job-cuts, which may increase the global unemployment rate. [4]

To counter these challenges, the concept of Industry 5.0 was introduced.

Industry 5.0

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Industry 5.0 proposed the collaboration of robots with the human brain that will work in support of humans rather than posing a threat to their jobs. [14] It aims to create more jobs for humans than it will be taking away. Industry 5.0 is in favor of protection of human race as well as environment sustainability. [7][8]

With the rapid technological innovations, each revolution might take less than a decade to evolve in quick succession one after the other. The first three Industrial revolutions took almost decades to wear out, but the current revolutions will quickly be overpowered by the next, after its implementation stage itself. [2] It's important to note that Industry 5.0 is an upgrade of Industry 4.0 and not entirely new.

Design Principles of Industry 5.0

Industry 5.0 includes 6R methodology and Logistics Efficiency Design (L.E.D.) principles.

The 6R methodology actually defines a business improvement model. Depending on the specific case, it can be considered as a business process improvement or a business process innovation. Therefore, the 6R methodology is subject to the rules, assumptions, and dynamics of process improvement efforts. Consumer brands should 'REBOOT' their businesses in view of the pandemic-induced disruption and changing consumer behavior. [24]

The 6R are:

1. Recognize: - Awareness of opportunities offered by Industrial Up cycling.
2. Reconsider: - Reconsider and Reengineer the business processes for following Industry 5.0.
3. Realize: - Post recognition and reengineering of business processes, it is important to realize the importance of business process improvement and innovation.
4. Reduce: - Reduction in the use of non-renewable resources inorder to maintain environment sustainability and achieve efficient outcomes is the essence of 6R.
5. Reuse: - Reuse of materials so as to minimize wastage and excess utilization of resources.
6. Recycle: -Finally recycling is done to promote greener environment and green manufacturing. The purpose is to target zero waste policy. [29]

Figure 3: 6R's of Industry 5.0

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In addition to this, L.E.D. [29] is designed for improving the efficiency global supply chains. L.E.D is the concurrent application of

1. Transparency
 2. Profit sharing
3. Efficiency in the supply chain.

Its goal is to eliminate the waste created by the current modern standard buyer-supplier business relations. [29]

Four types of waste [29] identified in Industrial Up cycling are:

> 1. Physical Waste: The actual physical waste introduced during and after the production. It is basically the trash. [29]
> 2. Social Waste: It is the unused potential of the manpower. People unemployed are at the heart of social waste. [29]
> 3. Urban Waste: This type of waste includes brownfields, empty spaces, and inadequate infrastructure. [29]
> 4. Process Waste: Overproduction, overstocking, empty transport vehicles on the roads are among the process waste. [29]

Features of Industry 5.0

Industry 5.0 consists of smart digital information and manufacturing technologies. It has majorly contributed towards the growth of various industries like healthcare, manufacturing and retail, mass-communication and many more. Solutions to challenges posed by COVID-19 pandemic could also be conceivable because of Industry 5.0. Major concern for Industry 5.0 is that it requires highly skilled workers with up-to-date technology for effective implementation.

1. Better automation [30] of the manufacturing unit as data is proposed to be real-time. It promotes process automation with complete transparency of all the processes related to humans and machines. [16] Moreover, due to increase in online shopping during the pandemic, stay at home culture and following of social distancing norms, secure and transparent transactions are need of the hour. Blockchain along with NFC/RFID technology can cater to this principle and help the stakeholders of garment retail to track the transactions. NFC (Near Field Communication) is a contactless technology that depends on RFC (Radio Frequency Field) that is designed with the intent of data transactions between two devices through a simple touch. Electromagnetic fields are used along with Radio-Frequency Identification (RFID) to track and identify tags attached to objects. [16][22] Combining these two with Blockchain solutions can result in the transaction to be more secure, transparent and the operations to be monitored effectively with the help of smart contacts. The NFC technology provides a safer connectivity to the data by providing information about the origin and certifications of the product and its lifecycle in the supply chain. [17][22] All this information served to be extremely beneficial to all the stakeholders, from suppliers to consumers. The supply chain was totally disrupted during the pandemic. So by combining these technologies the supply chain entropy can be reduced resulting in augmented visibility and transparency.
2. With advances in Artificial Intelligence, robots used in factories will assume more human-like features. **[30]** These are called Cobots (Collaborative Robots), which have cognitive features that can interact better with humans. The interaction between humans, computers and cobots will prove to be more enlightening and meaningful. [11][27]

It can be clearly depicted in the Figure 4 below where the hand of a businessman is having a good handshake with that of an Android robot. This shows the interconnection of humans with AI
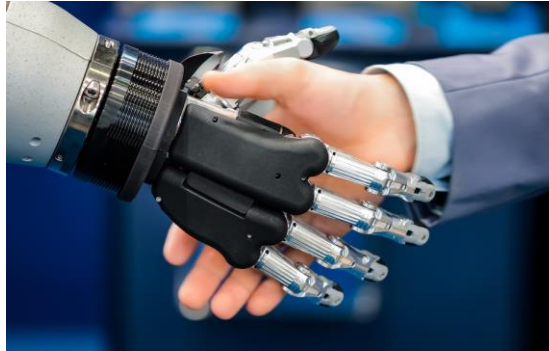

Figure 4: Handshake between a Businessman and an Android Robot

3. Industry 5.0 is all about alliance of machines and humans on the factory floors. There will be a creative human touch on the production instead of a standard robotic production. Human workers will assume better roles on the factory floor. This will lead to creation of new jobs. [29] This is depicted above in Figure 4.

4. Promotes personalization - This can be achieved by reintroducing the "human touch" in manufacturing of the products. It was studied that Industry 3 enabled mass production, Industry 4.0 promoted mass automation, but Industry 5.0 is about using the latest technology to customize and personalize the products and the production processes. Re-inventing creativity, by encouraging handmade-work paired with ultimate precision and productivity, by using Collaborative Robots or Universal Robots [32] is the trademark of Industry 5.0. The focus lies on providing a better customer experience with a personalized touch creating a happy and loyal customer and also an increase in the revenue of the service provider. This design principle works in tandem with the needs of clients of apparel industry where personalization is a statement of self-expression. [12][27] [29]

5. The pandemic accelerated e-commerce sales as stay-home phenomena drove significant purchases through e-commerce. It has even led to massive reverse migration, favoring companies with strong rural distribution due to increase in demands of rural consumers. Now the online retail companies are also eager to cater to the rural community thereby reducing the communication gap. [30]

6. The 'Endless Shelf' [25][26] is also the new reality of integrated commerce with high expectations to deliver shopper's experiences to access products when, where and how they want. Aimee Arana, the executive vice president of Digimarc pointed out that it will be difficult for small retailers and manufactures to adopt this technology where all apparel will require hangtags, labels and displays to enhance and ensure seamless shopper engagement, product discovery, as well as making it easy for shoppers to buy at the point of display without the need for traditional checkout. For this mobile handsets can be used for direct payments in-store and online transactions by scanning the barcode provided by Digimarc. [25][26]

7. Paperless technology is possible because of Machine Learning (ML) that provides accurate outcomes without detailed coding. Through reinforcement signals, the software is able to "learn" the best possible approach to achieve the desired goal. Machine

Learning algorithms are being trained to take on collaborative business processes and workflows for automation. This enables employees and the organization to go digital. Thus everything is digitalized reducing overhead of stationaries like paper. [1][8]

8. Industry 5.0 is also related to bionics [41] and synthetic bionics. Bionics is the imitation or abstraction of the inventions of nature. [18] In support of this there has been some progress in the field of manufacturing novel materials. [30] Industry 5.0 also paved way for Fashion 5.0 where they work in tandem to achieve efficient productivity and enhanced revenue generation.

9. It puts women at the forefront-Role of women will be extremely critical in shaping the 5th IR. For progress of any nation it is important to promote women empowerment. [1][8]

10. Uncaging recruiters - Industry 5.0 relies on human intelligence than ever before. For talent search, AI enables managers to capture best-suited profiles for job vacancies. [1][8]

11. Reinventing the work culture - The recent pandemic situation has done away with the 9-5 job timings and has paved the way for remote working culture. Innovative cloud platforms like InfinCE, provides a secure environment for online resource sharing, monitoring and video conferencing to support the work from home culture. [1] [8]

The Apparel Industry and Its Integration with Industry 5.0

Fashion 5.0 [34] is a high-value engendering fashion industry due to friendly collaboration between robots and people, promoting sustainability options. Some developments were made in this field as mentioned below: -

a. Punjab-based startup NUFAB developed a new non-woven fabric that will significantly reduce infection risk to frontline medical workers, who are facing heightened risk amid the Covid-19 pandemic. The fabric is soft, comfortable, lightweight, impregnable, permeable and above all breathable, which will help frontline medical workers immensely by reducing the infection risk up to 90 percent. Made without warp and weft weaving and knitting, the fabric is commonly used for making surgical mask, gowns, sanitary pads, diapers, etc. [20][21] It is used for making other hygiene products and can its application can be multifold such as in packaging, agriculture and automotive industries.

b. Another milestone was achieved in the development of MYLO, [40]
The new organic fabric grown from the filament-based root structure of mushrooms, mycelium. MYLO looks and feels like soft and supple leather.

c. Modern Meadow is a Startup venture that develops lab-grown leather and Bolt Threads is another Startup that turns spider silk into threads for fabrics.

d. Sleep in Pajamas are manufactured with a "bio-ceramic print" that combines body heat to produce far infrared radiation (FIR), which lessens inflammation, increases blood circulation, and helps the body to recover quickly.

e. Fashion 5.0 is all about neo-relocalization and intraglobalization. [34] The pandemic has made everyone realize that globalization couldn't be possible in such situations. Industries need to look for options locally and that the future of fashion is inclined towards more eco friendly options. Moreover to maintain social distance, virtualization and remote working is the new normal.

f. 360 degree reengineering applied to the apparel industry promoting [14] Fashion administrators are endorsing pre-owned, refurbished, repaired and rental fashion.

This trend has augmented during the pandemic. Thrift stores, recycled, pre-owned and rental products sales have increased. According to Everledger, [23] a digital transparency company, and Temera, [23] leader in Internet of Things (IoT) technology for the fashion industry, NFC [22] and blockchain can bring to light second hand market re-selling activities, fueling the need for imbibe sustainability by Gen Z of consumers. This will further support circular economy rather than linear economy.

Advantages of Industry 5.0[27]

Industry 5.0 is the revolution that majorly thought about re-introducing the human-touch to technology. Other benefits are highlighted.
   a. Cost Enhancement: Financial decisions and conditions will be improved since humans and machines will be working together. [27]
   b. Greener Solutions: With the new technologies coming in, concerns regarding the environment are being given utmost priority. DuPont Biomaterials and DyeCoo, [28] specializing in the development of cleaner dyeing technologies, has announced a patented, sustainable dyeing process for fabrics made from polyester or recycled polyester called Sorona. [28] The technology used in this dyeing method helps the designers to deliver quality-rich clothing having reduced environmental footprint. [27]
   c. Creative Personalization: Personalization is a key aspect of Industry 5.0. Machines are still involved in monotonous tasks, but with improved human interaction scope for personalization according to individual customers choices have increased. [27]

Challenges of Industry 5.0

To start something new and innovative always comes with challenges. Industry5.0 has its share of challenges. They are: -
   a. Legal issues and problems in standardization because of disproportion between technological development, social evolution and business environment due to a new Industrial revolution. **[27] [42]**
   b. Society is aging with larger number of senior citizens who may find it difficult to adapt with changes brought about by Industry 5.0 leading to difference in opinions between Seniors and Juniors.
   c. Overproduction can be there because of highly efficient manufacturing technologies. Transparency needs to be incorporated in all spheres of production. **[27]**
   d. More thought needs to be put on ethical behavior of the autonomous systems and their validation and verification needs to be checked from time to time. **[42]**
   e. Increased dependency on Information Technology and electricity to run the systems.
   f. Issues in human-robots co-working. Many personal, ethical, psychological, legal and social issues have surfaced as people do not know how to work with and handle robots. People are afraid that robots will overpower and replace them in the long run.
   All this can pose general reluctance to change by many stakeholders. How to manage robots and cope up with ever changing technology is also thought provoking.

Impact of Industry 5.0 [31]

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Industry 5.0 brought about the dawn of a new horizon impacting businesses and humans in many ways. They are mentioned below:

- Creative and personalized services and business models
- Enhanced revenue generation of business
- Automation and human involvement increases reliability and efficiency of productivity
- With transparency more stress is laid to adopt better and secure cyber security
- Utmost importance is for Machine and Human safety due to their collaboration.
- Lifecycle of product is increased
- Impact on environment due to Industry value chain has decreased because of adoption of renewable and greener resources.
- Increase in workers' education, skills and involvement for efficient productivity.
- Improvement of Socio-economic factors. [31]

Discussions

The basic principles of all the Industrial revolutions provided the impetus to follow and fulfill the vision and mission of any industry. The basic guidelines were provided by Industrial revolutions. The need for continuous evolution was also a signal, which each revolution promoted. To keep pace with the dynamics of consumer needs and wants and environmental challenges, continuous up-gradation and agility is required. Industry 4.0 and Industry 5.0 supported and transformed according to changing needs. COVID-19 pandemic tried to disrupt everything that took so long to establish. The Apparel Industry was one of most badly affected industrial unit. It adopted the technological advancements of the last two revolutions and has been trying hard for survival by reengineering and improving upon their flaws. A comparison of the features of Industry 4.0 and Industry 5.0 are mentioned below which aided the apparel industry to mitigate the impact of COVID-19 to some extent.

Comparative Analysis of Industry 4.0 and Industry 5.0 and futuristic Industry 6.0

Industry4.0 focuses on quantity and mass production due to automation whereas the focus of Industry5.0 is on a higher life standard and creativity with high quality custom made products. The motive of Industry5.0 is sustainability. [27] In the recent years many companies initiated programs for green manufacturing and production. This stimulated social responsibility projects and concept of corporate citizen started to trend in. The awareness for environmental protection is increasing among people. Now consumers are inclined towards products developed by companies promoting green production. So a positive and more progressive transition has occurred.

In table 1, we provide a comparison of Industry 4.0 and Industry 5.0. Note that both industrial revolutions have not completed their time frame. They are still in progression. A quick analysis of the comparison shows that industry 5.0 will have a wider and deep impact on society. [26] A Proposal for features of Futuristic Industry6.0 is also depicted in the table. This comparison is based on the current discussions. The actual revolutions may be quite different than what is actually discussed.

Table 1: Comparative Analysis of Industry 4.0, Industry 5.0 and Industry 6.0

S. No	Features	Industry 4.0	Industry 5.0	Industry 6.0
1	Automation	Main focus was towards complete	Main focus is to Balance machine-	Development of apps that will have

		Process automation. [27]	human interaction along with automation. [27]	Complete Automation with a click of a button.
2	Technology	Technology was given more importance. [27]	Need of developing a healthy interaction between humans and machines are given more importance. [27]	Convergence of industries with more creativity and resource sharing. [33]
3	Transparency / Virtualization	Virtualization was Promoted. [27]	Focuses on moving the wheel back to the real world environment. [27]	Due to convergence there will be higher transparency.
4	Job Opportunities	Reduction in jobs for humans because of automation. [27]	Aim to create more jobs for humans, as human-machine collaboration is the goal. [27]	More job creation as technology will span extra terrestrial area too. Example SpaceX [35] that aims to set up human base in Mars.
5	Inter-operateability / Interconnection	Better-connected and smart machines were introduced in the workspace. [27]	Introduction of cognitive computing with human intelligence. [27]	Enhanced cognition and appeal to work according to consumer preference. [33]
6	Offer/Demand Based production	Personalization or customization is not possible. Offer based production was there. [27]	Demand based production is promoted where products can be personalized and customized according to customer preferences. [27]	Totally demand based and customer-centric production to achieve zero wastage.
7	Resources	Both renewable and non-renewable resources are used as focus is on revenue generation and speedy production. [27]	Focus on using renewable resources as it promotes sustainable development and green manufacturing. [27]	Maximum utilization of renewable resources for greener environment.

The major limitation of Industry 4.0 is that it targeted complete automation disregarding human involvement. This was taken care in Industry 5.0, which provided an effective collaboration of humans and machines. In Industry 5.0 sustainable options are also considered and are in a nascent stage. The theoretical framework of Industry 6.0 aims to overcome the limitations of

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Industry 4.0 and Industry 5.0 and provide a synergetic approach for development of industries worldwide and also explore the universe for expansion.

Lookout For Features Of Industry 6.0-A Futuristic Proposal

Table 1 above gives a positive and hopeful revolution in the form of Industry 6.0, which would strengthen the hold of humans on earth. No machine can overpower the human brain. Computer and technology itself are outcomes of the powerful human brain and intellect. This notion will soon be justified and be worked upon by pioneers of Industry 6.0 and future revolutions. A theoretical proposal and research ideas in support for Industry 6.0 is discussed as : -

1. Convergence of ideas and industries- Industry 6.0 stresses on multi-resource pooling for upcoming industries. Each company can share their resources, thereby reducing extra overhead and investing in other arenas of production. [33]

2. Mentally directed CAD/CAM Brain/Machine Interface [33]- Most prominent example for this is the vision of Elon Musk where his company Neuralink [35] is planning to build a brain-computer interface (BCI) that will link human brains directly to computers. The goal of is to amplify the level of human intelligence and preemptively mesh it with the digital world so that humans can become stronger than machines and can refrain from being overpowered by AI.

3. Seizing the middle space- It could be done by creating an open online platform where buyers and sellers can trade, share information and swap insights, paving the way for a healthy ecosystem. This will eliminate the vicious trap of Amazon, Facebook, Alibaba and likes. [33]

4. Giving preference to customer influence and crafting engaging customer experiences. [33] A project of SpaceX called Starlink [35][36] targets to provide high-speed Internet to everyone, everywhere, and also to the population that terrestrial networks have failed to reach.

5. Investigating unfamiliar territory [33]- The futuristic project of SpaceX [35][36] that will help humans to shuttle between Earth and Mars is one such experience.

The Hyperloop [35][36] which is supposed to be a fifth mode of transport other than cars, airplanes, trains and boats, riders would now travel in a low-pressure tube, inside pod-like capsules supported by air and powered by a "magnetic linear accelerator."

All this can be possible by Elon Musk and his futuristic vision.

6. Safeguarding the environment - Maximum concentration is to protect the earth from disruption by proper utilization of resources. [33] The Boring Company [35][36] envisages this and is working on modification of TESLA- (Electric cars) by providing autopilot and driverless experience. The Netherlands has abundance electricity due to windmills and is the main market for TESLA cars.

7. Wearable Technology can also be called Smart fabrics/ electronic textiles /e-textiles/smart garments / intelligent fabrics. [43][44] The purpose of this is to provide added value to the wearer and to make it functional smart gadgets will be installed in textiles, apparels, shoes and jewellery to track and sense activity and give response accordingly. Research is going on to embed app connected hardware to monitor heart rate, oxygen level, sleep quality, body temperature, track activity and alert user from the invisible danger. [37] [44]

> a) MIT researchers created a system called ColorFab 3D that uses 3D printing to print objects with photochromic inks, which can change color when exposed to certain wavelengths of UV light. The first item ColorFab [37] created with the technology is a ring that can be programmed to change into a handful of preset, customizable colors.
>
> b) Google's Jacquard Threads [37] is also working on an innovative venture, Ebb, which will use technology to manufacture a color-changing fabric that could change color according to the wearer's mood or setting.

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c) In the Levi's Jacquard jacket, the Ebb materials could even help to conduct many activities that is currently done on the phone with color signals — for example, alert to an incoming call by changing the cuff color of the jacket. [37]

Continuous research and innovations are going on to practically implement all these ideas at a faster pace.

Conclusions And Future Directions

The provided review shows that the growth of digitization and its applications offered by Industry 4.0 created a base for quick and easy transition to Industry 5.0. The major drawback of Industry 4.0 highlighted is reduction in job opportunities of humans because increased machine and technology involvement in production and supply chain. But COVID-19 made us realize that technology is a boon with proper human connectivity. This paved way for smooth acceptance of Industry 5.0 paving the way for creation of Society 5.0.and Fashion5.0 where machine and humans work hand-in-hand for safeguarding the human society and the environment. It can be seen from the above deliberations along with relevant examples that technology has evolved for the better. Contactless shopping and virtualization of products were also promoted during the pandemic and researchers are working to mitigate the vast amount of human and economic losses incurred because of the pandemic. Many strategies for sustainable development of fabrics were introduced. Creativity was at the peak in all aspects during this period. The synergy of human and machine intellectual resources can build a greener and happy habitat and maintain ecological balance. Time is not far where each of the future Industrial revolutions will only cross the implementation phase signaling the advent of the next revolution. The future proposal is Industry 6.0 where there will be no interface with any machine, person, or drafting table/setup. An app will be created for all this. It's just a matter of click whereby a picture is taken and a command to make it is given. [27] The job will be done without any delay. Thus the requirement for coders, designers, data scientists, and application developers is exceedingly high. The future scope of this review is development of an application for managing the supply chain of the apparel industry by utilizing the features of Big Data and Industry 5.0 and Industry 6.0. The future of technology is unimaginable and is exciting. Looking forward to a better and newer revolution beneficial to the humankind and Mother Nature.

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